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Software development for home energy audits: Reducing energy consumption in Harrisonburg through technology

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Software Development for Home Energy Audits:

Reducing Energy Consumption in Harrisonburg through Technology

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An Honors College Project Presented to

the Faculty of the Undergraduate

College of Integrated Science and Engineering

James Madison University

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by Brantley Evans Gilbert
with Conor C. Cousins and Alyssa M. Felice

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Accepted by the faculty of the Department of Integrated Science and Technology, James Madison University, in partial fulfillment of the requirements for the Honors College.

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PUBLIC PRESENTATION

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1 Abstract

Fossil fuels play a vital role in our daily lives. Oil, natural gas, and coal powers our cars, heats our homes and water, and are used by power companies to generate the massive amounts of electricity used every day by the United States. However, this reliance on a finite source of energy is not sustainable. Fossil fuels such as these are non-renewable resources whose production will eventually be unable to keep up with the rate of consumption. Furthermore, the extraction of the stored energy in these fuels through combustion releases harmful substances into the environment, including toxins and greenhouse gases such as carbon dioxide. To end this reliance on fossil fuels we need to make fundamental changes in our globally collective behaviors. One of the easiest behavioral changes to make toward this goal is to focus on conserving energy at home. By reducing one's home energy usage through a home energy audit, a person can save money on electric and heating bills, help reduce his/her impact on the environment, and even potentially increase the market value of their home. Because traditional audit reports often fail to effectively change homeowner's energy consumption behaviors, the objective of this project is to determine if the home auditing process could be made more efficient and effective through the formation of volunteer auditing teams and the development of specialized software applications to address specific obstacles to energy usage behavior changes. To achieve this goal, we started the formation of a new campus organization, established the technologic infrastructure to store auditing data and develop future applications, acquired the necessary hardware to perform our audits, performed preliminary home energy audits, and developed a sizeable portion of the home energy auditing application to be used by the future members of the Madison Conservation Corps.

2 Introduction and Background

2.1 Origins of the Energy Crisis

Since the invention and widespread adoption of the internal combustion engine the United States has primarily used the combustion of organic substances such as coal, natural gas, and oil to provide most of its energy. Initially the reserves of these resources seemed to be so vast that little attention was given to their eventual depletion. Arguably the event that finally brought significant attention to the issue that the United States infrastructure's reliance on fossil fuels was unsustainable was the 1973 Energy Crisis. According to MIT professor Harvey Michaels, the United States "created a massive market chasm due to faulty information: consumers chose to build inefficient homes, buy cheaper inefficient appliances and heating systems, and build inefficient offices and factories, which drove up the total cost of satisfying their needs. As a result, our economy became a bastion of energy waste, a national security time bomb, and in 1973 it went off in the first Arab oil embargo." After years of declining domestic oil production, the U.S. increasingly relied on imports from the Organization of Arab Petroleum Exporting Countries (OPEC) to maintain oil production. In 1973 OPEC placed an embargo on oil, causing the price of energy in the United States to "quadruple within a 2-year period" (Michaels, 2002). Although the embargo was only temporary and the U.S. economy recovered, the episode showed how unprepared the U.S. is for the inevitable decline, and eventually the effective end, of fossil fuel production.

2.2 Residential Energy Usage and Behavior

Since the 1970s our per capita energy usage has increased. Today there are more cars on the road, more houses in neighborhoods, and more electronic devices than ever. Much of these increases have come from our behaviors at home and work. One study found that “commercial and residential buildings are responsible for 42 percent of all U.S. energy consumption and 41 percent of U.S. CO_2 emissions” (Palmer, 2011). How our behavior affects our energy consumption is reflected heavily in the seasonal variations in residential energy usage. Demand spikes in summer and winter, when we are spending more time indoors to avoid the heat or cold and increasing our air conditioning system usage, which has a significant impact on energy consumption. According to the U.S. Department of Energy, “virtually all homes that have air conditioning use electricity as the main source of cooling in the summer, while winter heating needs are met by a variety of fuels. Some homes use electric resistance heating and electric heat pumps, but even homes with other heating fuels such as natural gas or fuel oil still use some electricity to power furnace fans, boiler circulation pumps, and compressors” (U.S. Energy Information Administration, n.d.).

2.3 Paths to Greener Energy

To reduce our reliance on fossil fuels as a nation, we need to focus on two main goals: the adoption of alternative energy and reduction in the amount of energy we currently consume. Alternative energy refers to energy sources that have relatively no undesired consequences such as greenhouse gases for fossil fuels or radioactive waste for nuclear energy. Alternative energy sources are renewable and are thought to be “free” energy sources. They all have lower carbon emissions compared to conventional sources ("Alternative Energy," n.d.). This includes solar (radiation and photovoltaic), hydroelectric, geothermal, and wind. According to British

Petroleum and Royal Dutch Shell, two of the world's largest oil companies, "by 2050, one-third of the world's energy will need to come from solar, wind, and other renewable resources" ("Alternative Energy," n.d.). Climate changes, population growth, and fossil fuel depletion mean that renewable energy sources will need to play a bigger role in the future than they do today. Solar energy is one of the most likely future large contributors to the "green" electric grid. The most promising type of solar energy is called photovoltaic (PV). PV modules capture the sun's photons, particles that move at the speed of light, and convert that motion to electricity ("Alternative Energy", n.d.). Another type of solar energy system used is radiation, or thermal, solar. In this system water is run into a solar collector and is heated. The hot water is then used directly or to move a turbine. However, these technologies require a significant amount of research and funding to become feasible on a large scale. Wind energy, for example, is a "highly capital-intensive technology" that "suffers from the same lack of energy density as direct solar radiation" ("Alternative Energy", n.d.). While these technologies are in development, we must accept that we are currently unable to immediately make the infrastructure switch from fossil-fuel produced "dirty" energy to renewable "clean" energy. Therefore, the most effective action we can currently take is to reduce our overall energy consumption.

2.4 Home Energy Audits

This project focuses on conserving energy in the residential sector. A powerful first step in reducing residential energy consumption is the performance of a home energy audit. Generally, home energy auditing involves undertaking a thorough examination of a structure, such as a home or an apartment, and "determining how much energy is being consumed and roughly how much the consumption rate could be reduced through structural and behavioral changes" (Ingle, 2013). There are two primary factors in determining total home energy cost. The first is to determine how much energy each appliance in the house is using and whether those appliances can be replaced with energy efficient alternatives. This includes things such as incandescent light bulbs being replaced with fluorescent or LED bulbs, and older kitchen appliances being replaced with newer Energy Star™ certified energy efficient models ("High Electricity Bills?", n.d.). The second main factor in home energy consumption is the structure, building materials, and insulation of the building itself. This includes the energy used to heat or cool the entire building. Lower heating/cooling costs can be achieved by sealing up air leaks to prevent heated/cooled air from escaping and by adding insulation to areas with high heat transfer to the exterior. Other aspects of the structure, such as the number of windows, their material, and their orientation must be factored in as well.

2.5 Obstacles to Changing Home Energy Usage Behaviors

Undertaking tasks such as performing a home energy audit or even just swapping out older light bulbs for more energy efficient bulbs can make a difference in the daily energy consumption of a residential building. The question is, how can we convince people to commit to these actions? What is preventing many citizens from becoming conservation-minded? When it comes to home energy audits and retrofits, "the Home Performance Resource Center cites four common barriers: (1) ―consumer inertia attributed to time, costs, hassles, and general difficulties gathering information; (2) limited access to capital for financing improvements; (3) lack of public awareness; and (4) unavailability of home performance services in many locations" (Palmer, 2011). Generally, the higher the initial investment of a conservation measure, the less likely people will be willing to adopt it. This is due in large part to the fact that people are “far more likely to carry out pro-environment activities that have a low cost in money and effort than those which have higher financial and lifestyle costs” (Steg & Vlek, 2009, p. 309). Light bulbs are a prime example of this phenomenon. Light Emitting Diode (LED) and Compact Fluorescent (CFL) bulbs “use fewer watts and are still able to produce the same number of lumens (light) as the incandescent light bulbs” (“Rapid and Decisive Solution”, 2006). Along with their longer lifespan, this means that consumers save electricity, and therefore money, for each incandescent bulb they replace with CFL or LED bulbs. Unfortunately, these bulbs are significantly more expensive to purchase than incandescent bulbs. Along with the higher initial cost, many consumers are not sure how to compare energy efficiency because they are “used to shopping for light bulbs based on watts, or the amount of power light bulbs use” (“Rapid and Decisive Solution”, 2006). Knowledge gaps such as this present a major issue. Often, homeowners and businesses fail to invest in new “energy-efficiency equipment or building retrofits that would more than pay for themselves in terms of lower future energy costs” due to lack of “information on how to take full advantage of these opportunities” (Palmer, 2011). Our goal is to make the auditing process more effective and widely available, both economically and convenience-wise, by addressing these specific obstacles to energy saving behavior changes.

3 Materials and Methods

3.1 Stakeholders of Project

Before beginning any project, we must consider the stakeholders in the community that the project is addressing, both as potential project partners and as being potentially affected, positively or negatively, by the project. The first stakeholders to consider in this project are the students performing the audits, as these will be the students who will be investing their time to make a difference. In exchange for their time, they will gain valuable experience with home energy systems and conservation methods. This is particularly significant for engineering and ISAT students concentrating on energy and environmental sectors. The Harrisonburg homeowners receiving the audits are also primary stakeholders to consider, as these are the individuals that will have the opportunity to save the most economically from this project. Along with lower electric bills, the homeowners who receive the audits and attempt to make their homes greener can spread their knowledge and experience to other homeowners in the area who may have not considered receiving an audit yet. Performing complimentary energy audits may have an impact on individuals who depend on performing energy audits for a living. *Building Knowledge*, a local professional inspection service, charges $300 for an in-home energy audit (Meredith, n.d.). On the other hand, the project may provide a useful source of networking for these businesses if homeowners want a more thorough inspection after receiving the introductory audit. It would be an innovative idea to reach out to local contractors such as *Building Knowledge* to discuss potential sponsorship of Madison Conservation Corps.

Performing home energy audits across the community may even have positive effects on local real-estate values. According to the L.A. Times, “audits can save buyers thousands of dollars in future operating costs and pinpoint the specific features of the house that need correction to improve efficiency” (Harney, 2012). However, “if a person might find that this house is an energy guzzler they can either request the asking price comes down, the seller fixes the problems, or they walk” (Harney, 2012). If an audit is given before a house is put on the market, the value of the house can be maximized through adopting the energy saving recommendations found through the auditing process, in turn increasing the home’s value and positively impacting the realtors selling the house.

3.2 Project Targets - Homeowners

According to Linda Steg, “people are generally aware of the problems related to greenhouse gasses and global warming”, and are “concerned about these problems”, although there is “still confusion about the processes involved” (Steg, 2008). People know relatively little about the “energy use related to their own behaviors and how it contributes to these issues” (Steg, 2008). Although people are generally concerned with environmental and energy problems, many people put a “low priority on saving energy in their daily lives” (Steg, 2008), which is why it is sensible to focus on homeowners in this study. “It is believed that people are less likely to reduce their energy use when saving energy involves high behavioral costs in terms of money, effort or convenience. People are far more likely to carry out pro-environment activities such as recycling, which has a low cost in money and effort, than others such as reducing car use which have higher financial and lifestyle costs” (Steg, 2008). According to a similar study of pre-audit interview respondents, lowering energy costs emerged as “the most prominent motivation cited for seeking an energy audit" (Ingle, 2013). In addition, wealthy, educated and motivated people were the "dominant groups of people who entered the program" (Ingle, 2013). Given this information, by providing in home energy audits for free this project will target a wider number of homeowners to change their views on their everyday behaviors and work to decrease the amount of energy they use daily.

3.3 Scope of Focus - Harrisonburg

Because our organization will be run by James Madison University students, the primary focus of this project will be the local Harrisonburg community. The population of Harrisonburg, VA in July 2015 was approximately 52,538 people. Between 2010-14 there are an estimated 15,881 households with an average of 2.73 persons per household that produce a median household income of approximately $38,000 ("Housing Units", 2014). According to the US Energy Administration, the average annual electricity consumption for U.S. residential utility customer was 10,932 kWh (U.S. Energy Information Administration, n.d.). Based on these figures, Harrisonburg consumes roughly 170 million kWh per year. If this project can reduce this usage by just one percent, an annual reduction of 1.7 million kWh, at 12.65 cents per kWh (EIA, n.d.), it would save the community almost $220,000 a year.

3.4 Performing the Assessments/Auditing

Home energy audits are designed to show a homeowner specific performance details about their home. Ideally, our energy audits will be conducted at no cost to the homeowner. Home assessments would include the whole house, including "attic walls, foundation, windows, doors, ducts, and measurements of air leakage" (Ingle, 2013). The equipment that we plan on using include blower door tests, thermal cameras, and tablets. Blower door tests are an effective way to get the homeowner under the impression that the auditor is conducting a "sophisticated measuring tool and gives them a reason to get involved and ask the auditor questions" (Ingle, 2013). The auditors will consist of pairs of students working in teams: one person serving as the lead auditor while the other less experienced person is mainly focused on learning from the lead auditor. We expect the lead auditor to be JMU juniors and seniors, so when they graduate they will pass their knowledge to their younger partner. This should allow the organization to constantly recruit new students without requiring downtime for training after each graduation.

Homeowners being present throughout the audit allows the auditor to not only provide recommendations or upgrades for the house, but also provides an educational setting where the homeowner can learn skills and techniques that help them cut back on energy usage. The study that focused on behavioral perspectives with regards to home energy audits concluded "many homeowners identified the importance of face-to-face discussions with the auditor, and appeared to be energized by the auditor's enthusiasm. Homeowners frequently reported that the discussion with the auditor at the end of their visit was the most informative part of the entire process" (Ingle, 2013). We plan to provide asset assessments that focus on physical qualities. The ratings provided based on standardized assumptions about occupancy and occupant behavior to model under "standard operating conditions" (Ingle, 2013). When conducting energy audits our goal is to stress the importance of our data collection and recommended upgrades, however we will need to be aware of how our customers perceive our service. The interactions between the homeowner and the auditor are critical. The effectiveness of our feedback and recommendations are dependent on good relations between the auditors and the homeowners. One of the questions that will be tested through post-audit feedback is the effect of the auditor on the homeowner's likelihood to make an active behavior change. Our hypothesis is that if the homeowner is not satisfied or motivated by the auditors then it is unlikely that they we will see change in their behavior and energy usage. The application provides an easy-to-read detailed report and score for the home immediately after the audit. Instead of emailing a customer the score of their house a few days later, we hope that this approach will provide immediate feedback to motivate and provide an incentive for the homeowner to change their behavior. We plan on having energy efficient light bulbs ready to install immediately after the audit. This will hopefully provide extra motivation and encouragement for the homeowner to start making behavior changes that will reduce their energy footprint.

3.5 Measuring and Reporting Results

Throughout the in-home portion of the energy audit we plan on collecting data and providing feedback at the same time. The tablets will run an application that will allow the auditors to collect, store, and provide feedback to the homeowner. The application provides a free report of their home energy score along with specific recommendations. The feedback will consist of an energy estimate of their current usage and an energy usage estimate with recommendations and upgrades, include the costs and savings of such recommendations to show the homeowner exactly when the upgrades will pay for themselves. Once we show the homeowner that they can save money from the recommendations we believe that it will give them incentive become more aware of their current behavior. For example, we want the homeowner to keep in mind when leaving the lights on that "ten light bulbs use 6 cents an hour. If you use those bulbs for 6 hours a day, it'll cost you 36 cents a day or about $10 a month. That may not sound like a lot, but $120 a year for lights that you may not be using all the time does." ("High Electricity Bills?", n.d.). We want the homeowner to see the direct benefit that they will receive from an energy efficient home, as well as the long-term savings.

The Energy Performance Scorecard is heavily used in the Pacific Northwest and it essentially provides a "nutrition label for homes" to give potential home buyers a full look at what they are purchasing. The application that we are developing will provide the same feedback that this scorecard contains ("EPS", 2010). We are also developing a website that will connect to our application. This website will store and provide online reports and grades for the homeowners that receive an audit. This website will show homeowners how efficient their home is relative to the rest of their neighbors in their community. We hope this will provide a competitive game-like environment for communities where we could have energy statistics on each home and potentially allow each user to compete with other users. According to a homeowner "when you hear that your neighbor pays half of

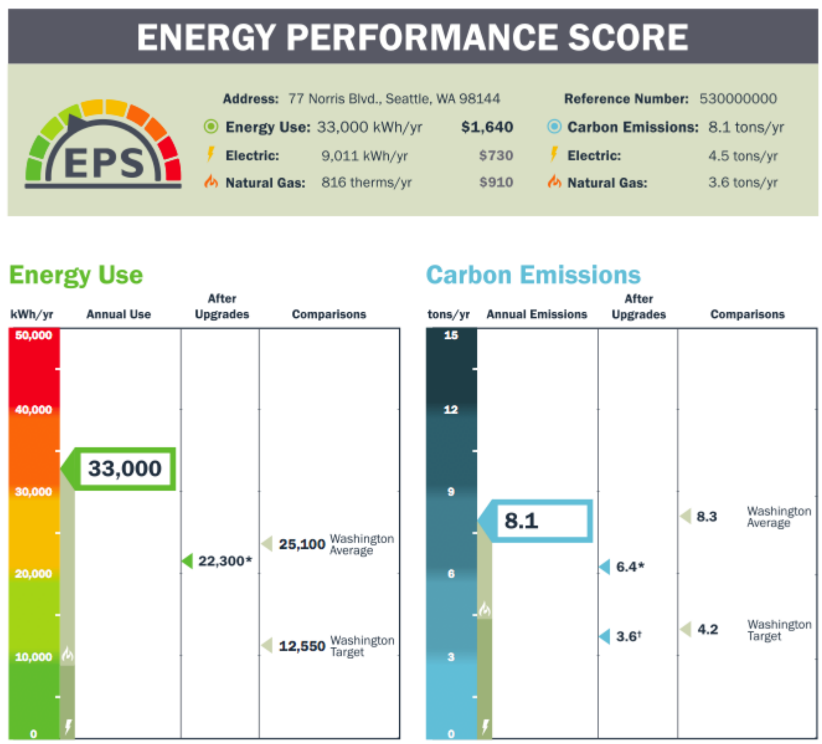


Figure 1: *An example of an Energy Performance Scorecard given to a homeowner after an audit is performed ("EPS", 2010).*

what you do to heat his home, that has an impact" but "spreadsheets and brochures that list projected costs and expenses don't work" ("Why People Aren't Sold on Energy Efficiency", n.d.). The homeowners hopefully will see the benefit that other people are receiving from energy efficient upgrades and this will provide incentive to join the energy conservation and reduce their home output. The long-term benefit for our project of having the website is that it will allow us to see if our recommendations are working over time.

3.6 Creating Guidelines for Future Studies

To give the homeowner a more accurate scorecard the auditor should have the details and history of the homeowner's electricity bills. This will give them information on the performance of the home before they show up to conduct the audit. Also, the billing and usage history will give the auditors an idea of how much improvement they can make on a home. Marketing to a specific audience that has shown prior interest in home energy audit and conserving energy within the home increases the chance that people will sign up for an audit. The marketing value of a home is an interesting section of our home energy audit project because it makes the energy efficiency score of a home a potential factor that a seller might consider. For example, in the study conducted on behavioral perspective on home energy audits (Ingle, 2013) they talked to professional realtors in the Seattle area and most agreed that the Energy Performance Scorecard was a "market transformation view on how energy labels might influence the real estate market, by allowing buyers to compare homes based on their energy use, thus increasing the demand for, and value for efficient homes, and ultimately motivating homeowners and builders to make energy improvements and increasing the overall efficiency of the housing stock".

4 Results

Before we began developing our application and forming our organization, we needed to perform a home energy audit manually to better understand the process and what advantages our application should provide over a manual audit to achieve our goal of making the audit process more simplified and less time-consuming. We decided to audit each team member's residence, recording our measurements in a spreadsheet and using formulas to calculate the results. We found the process to be slow and repetitive, taking an average of three hours per residence. After performing our preliminary home energy audits and determining what data should be collect and how the results should be calculated, we started structuring our organizational and technical frameworks. Working alongside our adviser, Dr. Morgan Benton, we established the Madison Conservation Corps and began recruiting students from the ISAT department to join our project. Since we decided to use tablets for auditing due to their portability and ease of use, we decided to use the Ionic Framework for native mobile development (Drifty Co., 2017). This allows for the development of native iOS and Android apps using common JavaScript-based web design

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	BRANTLEY'S ROOM													
2	Appliance	Current (A)	Voltage (V)	Watts (W)	Daily Hours On	Left Plugged-In	Leaking Watts	Monthly On-Time	Monthly Off-Time	Watt-Hours On	Watt-Hours Off	Total Monthly Watt-Hours	Total Monthly kWh	Monthly Cost @ $0.12 / kWh
3	Laptop			170	4	Yes	1.3	120	600	20400	780	21180	21.18	2.5416
4	Fish Tank Pump			3.2	24	Yes	0	720	0	2304	0	2304	2.304	0.27648
5	Fish Tank Heater			50	24	Yes	0	720	0	36000	0	36000	36	4.32
6	Fish Tank Light	0.5	120	60	9	Yes	0	270	450	16200	0	16200	16.2	1.944
7	Minifridge	1.65	115	189.75	24	Yes	0	720	0	136620	0	136620	136.62	16.3944
8	Television	1.2	100	120	2	Yes	4.3	60	660	7200	2838	10038	10.038	1.20456
9	Coffee Maker			1460	0.5	No	0	15	705	21900	0	21900	21.9	2.628
10	Router	0.5	100	50	24	Yes	0	720	0	36000	0	36000	36	4.32
11	Printer	8.8	120		0.25	No	0	7.5	712.5	0	0	0	0	0
12														
13												Total:	280.242	33.62904
14	LIVING AREA/KITCHEN													
15	Appliance	Current (A)	Voltage (V)	Watts (W)	Daily Hours On	Left Plugged-In	Leaking Watts	Monthly On-Time	Monthly Off-Time	Watt-Hours On	Watt-Hours Off	Total Monthly Watt-Hours	Total Monthly kWh	Monthly Cost @ $0.12 / kWh
16	Fridge	6	115	690	24	Yes	0	720	0	496800	0	496800	496.8	59.616
17	Coffee Maker			1000	0.25	No	0	7.5	712.5	7500	0	7500	7.5	0.9
18	Toaster Oven			700	0.25	Yes	0	7.5	712.5	5250	0	5250	5.25	0.63
19	Microwave			1250	0.5	Yes	3.2	15	705	18750	2256	21006	21.006	2.52072
20	Oven			1500	1	Yes	0	30	690	45000	0	45000	45	5.4
21	Dishwasher			600	1	Yes	6.4	30	690	18000	4416	22416	22.416	2.68992
22	Television			50	4	Yes	4.3	120	600	6000	2580	8580	8.58	1.0296
23														
24												Total:	606.552	72.78624
25	LAUNDRY ROOM													
26	Appliance	Current (A)	Voltage (V)	Watts (W)	Daily Hours On	Left Plugged-In	Leaking Watts	Monthly On-Time	Monthly Off-Time	Watt-Hours On	Watt-Hours Off	Total Monthly Watt-Hours	Total Monthly kWh	Monthly Cost @ $0.12 / kWh
27	Washer	6	120	720	0.5	Yes	0	15	705	10800	0	10800	10.8	1.296
28	Dryer	23	120	2760	0.5	Yes	0	15	705	41400	0	41400	41.4	4.968
29														
30												Total:	52.2	6.264

Figure 2: *A sample of our manual audit measurements and calculations. Most of these rows could be calculated by our application, reducing the amount of time need to complete an audit.*

frameworks, thereby streamlining our development time by allowing us to use our previous web development experience. To store data relevant to performing audits and maintaining the organization structure, such as auditor status, home addresses, previous audit scores, and appliance information, we needed a centralized database. We decided to use MySQL, a relational database capable of storing substantial amounts of records and efficiently searching and updating them.

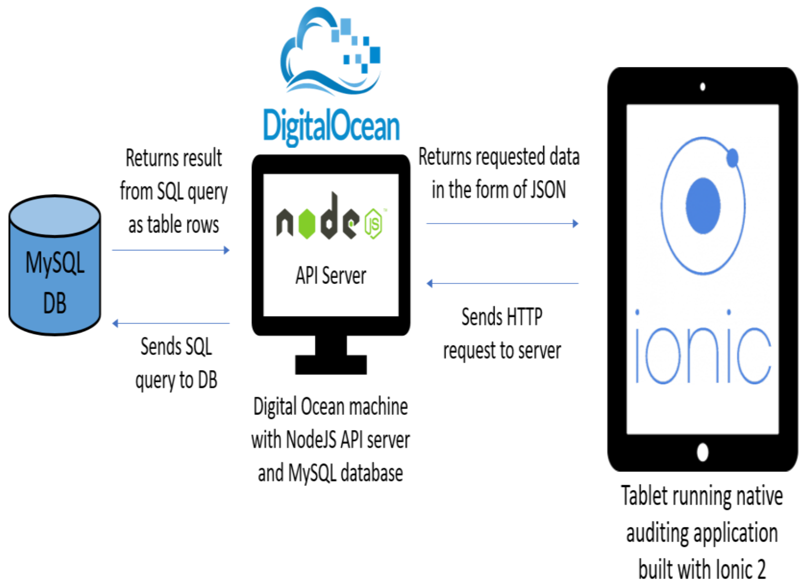


Figure 3: *A simplified view of our application's data flow. All the software used, aside from the server host, is open-source and free to use*

For our application to put data into our database and retrieve it while in various areas of Harrisonburg, we needed to host our MySQL database on a public server, meaning a machine that can be reached from anywhere with an internet connection. DigitalOcean was the remote server hosting company we chose due to their ease-of-use and straightforward pricing model. Because our mobile application is unable to communicate directly to our database, the last part of our application's system was to develop an Application Program Interface (API). This allows the application to send HTTP requests to a web address and receive data back in a mobile-friendly format. For this we used Node.JS and Express.JS to turn the requests from the app into the Structured Query Language (SQL) used by our MySQL database.

Next, we began working on developing the application itself, using the manual audits we performed as guidelines to how our app should be structured. When auditing a house for the first time, the auditor will first enter some basic information about the residence and the residents, including the address, a phone number and/or email, and whether the residence is the residents' permanent address. The auditor can then begin an audit on the newly entered residence, or begin a new audit on a residence already in the system by searching through previously audited addresses. The audits themselves are broken into two parts: Whole House and Room-By-Room. The Whole House page includes inputs for data such as building type, building year, orientation, climate control, and water heating. Room-By-Room is where an auditor goes through each room, records the insulation, number of windows, appliance information, and lightbulb information. After both sections are complete the Results page displays how much energy is currently being used and which behavior changes can be used to reduce this amount of usage. The application is still in development and will be presented at the ISAT Senior Capstone Symposium on April 21st, 2017.

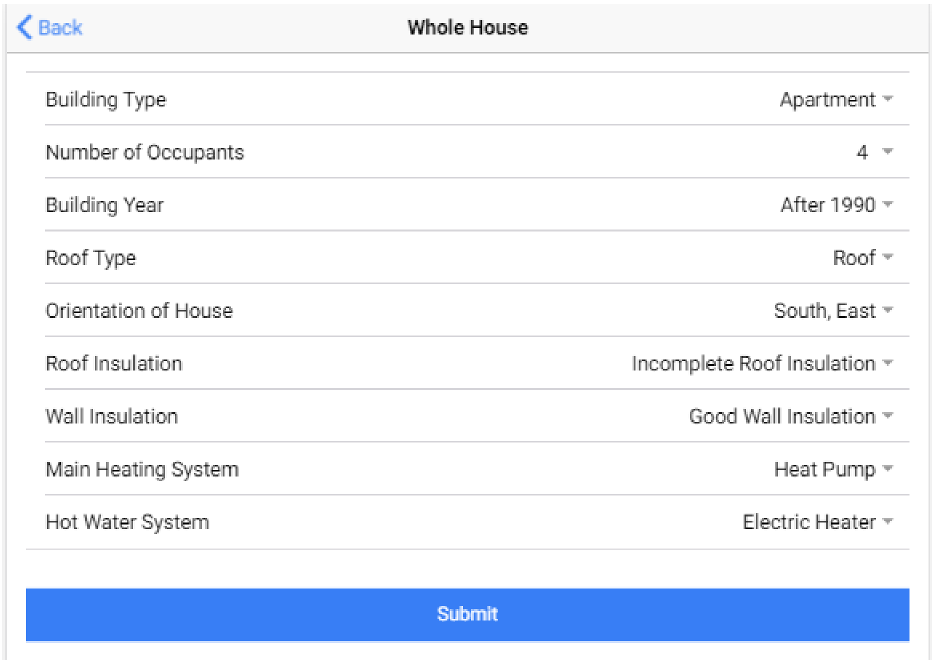
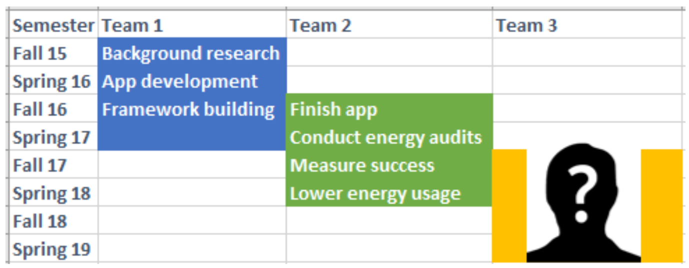


Figure 4: *The Whole House section of our application (work in progress). Auditors must complete this section and Room-By-Room to view the audit results.*

5 Discussion

When we began this project, we planned on fully finishing our application, starting an official JMU home auditing club, performing home energy audits around Harrisonburg, and measuring the reduction in energy usage across the Harrisonburg area, all within two semesters. This was a drastic overestimation of the time and effort needed to complete these tasks. The biggest obstacle we encountered was our limited knowledge of application development. Although we were unable to use our application in a real-life auditing scenario, we developed a scalable system that the future Madison Conservation Corps members will continue to improve and use in the local community. Despite our limited results, we gained a lot of knowledge in web and application development, database management, and user interface design. We secured funding from the ISAT department to purchase an iPad and a special camera that will allow us to measure room dimensions directly from our app. The Madison Conservation Corps members for next year have already set goals to complete the application and begin auditing, and we are still recruiting new members to continue development and volunteer to perform the audits throughout Harrisonburg.



Semester	Team 1	Team 2	Team 3
Fall 15	Background research		
Spring 16	App development		
Fall 16	Framework building	Finish app	
Spring 17		Conduct energy audits	
Fall 17		Measure success	
Spring 18		Lower energy usage	
Fall 18			
Spring 19			

Figure 4: *A graphic from next year's capstone proposal showing the long-term timeline of the Madison Conservation Corps.*

6 Conclusion

After extensive research on the obstacles to residential energy conservation and the role home energy audits play in changing energy usage behaviors we laid down the foundations for a new organization at James Madison University, the Madison Conservation Corps. We performed home audits manually and developed a full-stack system for streamlining home energy audits. In the process, we learned a great deal about both energy audits and various aspects of software development. We designed a tablet-optimized user interface, learned how to secure our application using authentication protocols, and created an API for our mobile app to communicate with a central database. Future work will involve finishing the organization management aspect of our app and testing it in the field to measure its effectiveness in changing home energy conservation behaviors.

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